The GENERAL RADIO
EXPERIMENTER

VOL. 2 NO. 9

FEBRUARY, 1928

The General Radio Experimenter is published each month for the purpose of supplying information of particular interest pertaining to radio apparatus design and application not commonly found in the popular style of radio magazine.

There is no subscription fee connected with the General Radio "Experimenter." To have your name included in our mailing list to receive future copies, simply address a request to the
GENERAL RADIO CO., Cambridge, Mass.

Equipment of the Service Laboratory

By C. T. BURKE, Engineering Department

The equipment of a service laboratory will depend on the scope of the work attempted, and on the resources available. Some of the larger city establishments specializing in service work and custom set building have well equipped laboratories which rival those of some manufacturers. Such equipment is obviously out of the question for many smaller establishments. Yet from a small beginning an excellent laboratory can be built up, which will meet the needs of the average service company.

The first requisites of a radio laboratory are meters. Direct current voltmeters for 6, 150, and 500 volts will be required. The 150 and 500 volt meters should have a resistance of 750-1000 ohms per volt in order that they may be used for checking socket-power plate supplies. The advent of the electric set and socket-power devices makes a collection of alternating current meters also necessary. A. C. voltmeters of 3, 10, and 150 volt ranges will be found sufficient. Direct current meters of 5, 10, and 25 milliampere ranges will be required. For measuring filament currents, hotwire meters may be used on either direct or alternating current. Suggested ranges are 100 milliamperes, 1, 5, and 10 ampere. With these meters, a great deal of inform-

Type 388
Vacuum Tube Reactivator

ation concerning the set may be obtained. Tube voltages and currents can be checked, showing up open circuits, or defective tubes, batteries or socket-power units. As a matter of fact, a small service establishment could get along with no other equipment than an assortment of meters, since most of the trouble experienced with receivers is traceable to the causes just mentioned.

If much testing is done, one of the commercial set-testers will be found of invaluable assistance. These instruments consist of milliammeters and voltmeters mounted in a case with switches and shunts which permit running through the various tests rapidly when the plug provided is inserted in a tube socket.

In the General Radio Type 388 Vacuum Tube Reactivator is combined a rapid test for tubes with a means for reactivation of the thoriated type. This instrument is operated from any 60-cycle 110-volt line. A meter indicates whether the tube has the proper emission. If the emission is low, proper voltages for flashing and cooking are applied by placing the tube in the proper socket and depressing a key.

Next to the current and voltmeters, perhaps the most useful instrument is the ohmmeter. With this instrument, open circuits, and short circuits can be quickly detected. The actual resistance of the circuit between two points is indicated, revealing partial short circuits, wrong connections, reversed transformers, etc. The General Radio Type 287 Ohmmeter consists of a battery, resistance, and milliammeter, calibrated to read directly in ohms the circuit to which it is clipped.

A source of high voltage is of increasing importance, not only as a plate supply for receivers under test, but also for testing bypass and filter condensers, which do not always show a low voltage short circuit, as well as the insulation of various instruments. High voltage supplies satisfactory for this purpose have

Temperature Coefficient in Resistance Materials

By C. C. SWIFT, Engineering Department

In most cases, resistance in a conductor may be treated as a constant, but in cases where precision in measurement is required, its vagaries must be taken into account. The one big trouble found in most resistance materials is that their resistances vary considerably with temperature. As there is always a rise of temperature with current flow through a resistance, this property is a great hindrance to accuracy.

It comes about in the following way: To force a current of I amperes through a conductor having a resistance of R ohms, a voltage E=IR is required, so that the power expended in the conductor is EI watts=(IR)I=I^2 R watts. This power is transformed into heat. The temperature of the conductor is determined by the amount of flow of the current, the resistance of the conductor, the area of the conductor, and the rate of dissipation of heat through whatever medium surrounds it. The rise of temperature in a conductor would not bother us any if the resistance remained constant under all usable temperatures.

The *rate* of change of resistance with temperature is called "temperature coefficient." The method of obtaining the temperature coefficient of a conductor is a little involved, but makes a good experiment. Briefly, a given resistance is measured very carefully at temperature points ranging between 0° and 100° C and its per cent change in resistance is plotted against the corresponding temperatures to form a curve on a graph. The maximum change in resistance divided by the number of degrees in the range gives the average temperature coefficient per degree in per cent. The term "per cent" is then dropped by moving the decimal point two spaces to the left. The range must always be stated because the temperature coefficient varies with the temperature, i. e., the variation of resistance with temperature is not uniform.

The causes of temperature coefficient have not been satisfactorily explained. What appears to be a good reason when applied to one material is not sufficient to explain the action in another material. About the most that can be said is that resistance variations are the result of temperature changes on molecular activities. We know that some metallic materials like tin and lead when cooled to -269° C have shown such a low resistance that a current flow induced in them will persist for several hours.

Of course it was recognized long ago that no precision work in electrical measurements could be done unless we could find resistance material with a low temperature coefficient. It was found that, although all elemental metals possess a positive temperature coefficient, alloys such as copper with nickel or manganese, for some reason have negative coefficient properties. By combining these materials in proper proportions determined by experiment, commercial wire is produced, having a coefficient as low as .00001 per degree C, between 20° and 100° C. Wire of this kind is made in Germany and in this country and is obtainable in all sizes from number 1 to number 40, B, and S. gauge.

In using special wire which possesses a low temperature coefficient it has been found that bending of the wire, either in insulating, spooling or winding on forms, almost always has the effect of raising the specific resistance. In course of time the specific resistance gradually drops back to its stable value, the process usually taking some months. This process is called ageing. A method of artificial ageing is sometimes used and seems to work well with some kinds of wire, but is not so successful with others. The process consists of placing the resistances after winding, in an electric oven, heating them to 250° F, holding them at that temperature for from two to three hours and then letting them gradually cool in the oven. This heat treatment seems to restore the molecules of the material to normal position and bring the specific resistance down to its stable value. The most satisfactory method of ageing wire discovered so far is that of small temperature change with long time. This is accomplished by storing away finished wound units in a cabinet exposed to ordinary changes of room temperatures for from four to nine months. Wire thus treated drops to its lowest normal resistance. The units can then be calibrated, set to correct reading including switches or contact devices, and assembled in completed cabinets.

There are many materials used for their resistive properties and they may be classified into two groups: metallic and non-metallic. Under non-metallic are listed the carbon and graphite and their kindred substances; the metallic group includes iron, brass, nickel-silver, and alloys of nickel, chrome, tungsten, manganese, and copper. For purposes of generalization we will call the non-metallic materials the carbon, and the metallic materials the wire resistances as it is in the form of wire that most metallic resistance is used.

Carbon substances have a negative temperature coefficient and no way has ever been found to compensate for it. A bad feature of carbon resistances is the difficulty with which contact with them can be made. However, carbon is a convenient and inexpensive material and may be used in many places where precision of action is not demanded.

Metallic resistances are made in many forms, the design depending on the current-carrying capacity desired. For resistances of light current capacity for grid leaks and oscillation suppressors, a glass tube is electrically coated with a resistant metallic film, usually of tungsten. The tube is provided with contacts at the ends and used as a cartridge resistance mounted in clips. This form is very convenient as it allows of quick change. It is claimed that such metallic grid leaks have superior stability, but they are not accurate for any but very small currents.

By far the greatest use of resistance is in the form of wire. The wire is usually wound on a form of such material as to withstand any heat that the resistor is designed for. The size of the wire is determined by the current it is to carry

(*Continued on page 4, col. 2*)

The Impedance Adjusting Transformer

By C. T. BURKE, Engineering Department

Since this matter has already been made the subject of an "Experimenter" article, perhaps some apology is necessary for bringing it up again. The writer has been moved to the preparation of this article by repeated evidence of misunderstanding of the function played by transformers designed to "match" impedances, culminating in the following evidence of a slight mental haze surrounding the subject even in such usually well informed quarters as the laboratory of "Radio Broadcast." "A little consideration will show that if the primary impedance of this transformer is equal to the tube impedance and if the secondary impedance is equal to—'matches' is the usual word— the load impedance, one-half the voltage existing in the plate circuit will be expended in heating the plate. It is obvious then that the primary impedance again should be several times that of the tube."

An old professor of the writer's, an experienced author of text books, used to warn his classes that the phrase "it is obvious" is the invariable resort of an author when the conclusion it precedes is far from obvious from the premises.

In the first place, why is an impedance adjusting transformer? Briefly, when circuits of greatly differing impedance are connected together the efficiency of transfer from one circuit to the other depends on the relation between the impedances of the circuits. It may be demonstrated that the maximum transfer of energy is obtained when the impedance of the circuit in which the energy originates equals that of the circuit to which it is delivered, or, as it is usually expressed, when the impedance of the "source" equals that of the "sink."

Ordinarily, the impedances of the source and of the sink depend on factors of design which may not be altered to improve the impedance relation. This is where the transformer comes in. Suppose a source has an impedance of Z_1 and generates a voltage of E, and must be coupled to a sink having an impedance of Z_2. Maximum power transfer occurs when Z_2 equals Z_1. To the source this means that the impedance Z_2 must look equal to Z_1, that is, it must take the same current from the source as a sink impedance equal to Z_1 would. It is well known that in going through a step-down transformer, the voltage is divided and the current multiplied by the turns ratio of the transformer.

If E_2 = secondary voltage

I_2 = " current

I_1 = primary current

$$I_2 = \frac{E_2}{Z_2} = \frac{E_1}{N Z_2}$$

$$I_1 = \frac{I_2}{N} = \frac{E_1}{N^2 Z_2}$$

But for maximum energy transfer, —

$$I_1 = \frac{E_1}{Z_1}$$

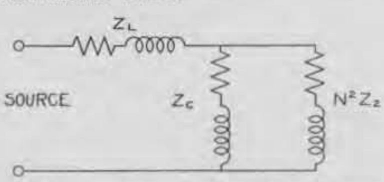
Therefore

$$\frac{E_1}{Z_1} = \frac{E_1}{N^2 Z_2}$$

and $N = \sqrt{Z_1 / Z_2}$

In other words if the sink is coupled to the source with a transformer having a turns ratio N, equal to the square root of the ratio of the impedances, the circuit will act just as though the sink impedance equals that of the source.

So far nothing has been said of the effect of the transformer impedance, the action of the unit in "matching" impedances depending entirely on its ratio and having nothing to do with the impedance of the transformer *per se*, by which is meant the impedance measured across the primary with the secondary open circuited. The transformer impedance does have an important effect on the efficiency of the device which may be shown from the approximate equivalent circuit shown below.



The circuit consists of an impedance Z_L, (including the ohmic resistance and leakage reactance) in series with a parallel circuit consisting of N^2 Z_2, the sink impedance as modified by the transformer, and Z_C, the open circuit impedance of the transformer.

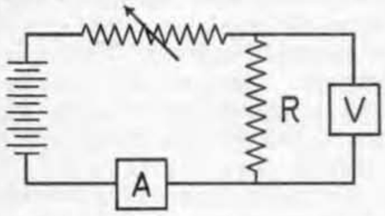
The transformer impedance forms a shunt across the sink, drawing current which increases the losses in the source and does not flow on into the sink. Proper design demands that the transformer impedance be enough larger than the reflected impedance of the sink to insure that practically all of the current shall flow through the sink. If the transformer impedance is equal to the tube impedance, only half the current output of the source would get into the sink, and *more than half* the voltage existing in the plate circuit would be lost. If the turns ratio is such as to make the equivalent sink impedance equal to the source impedance, and the transformer impedance is high, half the voltage will appear across the transformer, and half will be lost in the plate of the tube. This is the condition for maximum power output of any electrical device. The fire department arrives, of course, long before the condition of maximum output is reached in conventional power machinery.

To sum up, the matching function of the transformer is dependent on its turns ratio. The transformer impedance must be high enough to prevent appreciable shunting. The transformer does not, as one might be led to believe by reading the article already referred to, introduce factors of 2 at convenient points in a mathematical proof.

It is not always practical to obtain a sufficiently high primary impedance to prevent shunting. In intertube coupling transformers, the reflected impedance is higher than it is feasible to make the transformer impedance at low frequencies, and hence the shunting effect controls the behavior and design of the device. In another portion of the article referred to above, factors of cost, size, and coil distributed capacitance are ignored (illustrating the perils of "arm chair" engineering) and it is proved that inter-tube coupling transformers should have a ratio of about 9, although an error in extracting a square root gives a result of 3. The best commercial transformers have a ratio of about 3, so that the error in mathematics just offsets the error in assumptions. It is dangerous, however, to depend on such fortuitous circumstances in practical design problems.

(*Continued from page 1*)
been described in recent issues of the "Experimenter." When the power supply is to be used for testing, it will be found useful to install a voltmeter permanently across the output.

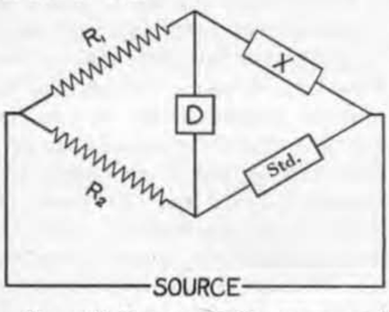
In testing a receiver for sensitivity and range, a radio frequency oscillator is essential, since transmission from broadcast stations cannot usually be relied upon for testing. A satisfactory oscillator of low power is very easily constructed from standard receiver parts, using a 199 tube. If provision is made for modulation of the oscillator the audio frequency response of the receiver may be taken at the same time, using either an audio oscillator, or phonographic pickup for modulation.



Resistance measurements may be made by means of a voltmeter and ammeter connected as shown in the diagram.

$$R = \frac{E \text{ (Voltmeter reading)}}{I \text{ (Ammeter reading)}}$$

The proper meters and a source of the right voltage are not always available, particularly when high resistances are to be measured. In such case, a simple bridge may be constructed which can be used for inductance and capacitance measurements as well.



R_1 and R_2 are ratio arms, and may be used in a variety of bridge circuits. The standard is a standard of resistance, inductance or capacitance, as may be required. For resistance measurements, the source may be a battery. For inductance and capacitance measurements it should be a 1000-cycle buzzer, phones being used to balance the bridge.

In the more ambitious laboratories permanent set-ups of bridges for special purposes will be desired. These include inductance bridges and several types of capacitance bridges for various purposes. The General Radio line includes the type 240 direct reading capacity meter for by-pass and filter condensers, the type 383A capacity bridge for measurement of tube capacitances, the type 383B capacity bridge for measurement of broadcast tuning condensers, and matching of sections; and the type 216 Bridge for measurement of capacitance and resistance of condensers up to 1000 MMF capacity.

(*Continued from page 2*)
and the temperature at which it is to run, and the length of wire then becomes dependent upon the resistance per foot of the particular size and kind of wire used. Potentiometers, rheostats, voltage dividers and biasing resistors are made in this way.

Another convenient form for metal resistances is that of a ribbon. As previously noted, the temperature of a current-carrying wire depends not only on the current flowing, but upon the surface area of the wire and its specific resistance and shape, and the nature and temperature of the surrounding medium, generally air. A wire of round cross section has a shorter perimeter than any other cross section of the same area, and therefore in a given length has a smaller area. In a ribbon shape, however, the outside area of a given length and cross section becomes greater as the ribbon becomes thinner. The ribbon shape, therefore, will dissipate heat faster than the wire shape, everything else being constant, and its temperature will be lower.

In the laboratory, resistances play an important part. They must have known values and it is necessary that they be accurate at any temperature to which they are likely to be subjected. Such resistances are made by the General Radio Company. A full line of fixed resistors arranged in steps of 1,000 ohms is made, so that the experimenter may have under his hand any value of resistance desired. Boxes with mounted switches are made with which the experimenter can immediately provide his circuit with any resistance he wishes, and can then vary the resistance in any way. All these standards are wire wound. In order that the resistances may be accurate when used with alternating current of high-frequency, the wire is wound in such a way that all units are non-inductive.

A complete description of the laboratory resistors, fixed and variable, made by the General Radio Company, may be had for the asking by sending for Bulletins 2050, 2100 and 2150.

Modifications of the Type 361-A Vacuum Tube Bridge

The advent of the A. C. Tubes has occasioned the need for a slight modification of the General Radio Type 361-A Vacuum Tube Bridge in order that data may be obtained on both A. C. and D. C. Tubes in the regular manner. The Bridge as modified will be known as the Type 361-B and will be supplied in this form to future purchasers.

For the convenience of our customers who have already purchased the Type 361-A Bridge, we have made arrangements whereby these Bridges may be returned to our factory for modification at a net cost of six dollars ($6.00). The Socket Adapter supplied with the Bridge should be returned at the same time.

To accomodate the various types of tubes and styles of bases, we have developed the following adapters:

Type 361-34 for use with the large old-style UV tubes, such as UV-200.

Type 361-35 for use with the old-style small Base UV tubes, such as UV-199.

Type 361-37 for use with D. C. tubes fitted with the standard UX type of base.

Type 361-38 for use with the 4-pronged A. C. tubes fitted with the standard UX type of base, such as the UX-226, etc.

Type 361-39 for use with the 5-pronged separate heater A. C. tubes fitted with the standard UY type of base.

The various adapters, which may be ordered separately, carry a net price of three dollars ($3.00), each.